

POWER MANAGEMENT FOR THE SMART BUILDING

Design Guide



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Figure 1. Building Automation

Introduction

Buildings—with a carbon footprint even greater than that of the transportation sector—account for a significant portion of the total energy consumption in the United States. The American Architecture 2030¹ standard recently issued a challenge for all existing buildings to cut energy use by 50% compared with 2005 levels, and for all new buildings to be completely carbon neutral by 2030. In other words, they should supply most of their energy needs using renewable sources. Many large and medium-sized cities already require commercial building owners to disclose actual green building performance² to tenants, buyers, and, in some cases, the public. By utilizing modern control and automation techniques, smart buildings can have significant energy savings, protect the environment, improve the health and safety of its occupants, and enhance quality of life.

Designing for building automation (Figure 1) introduces issues of energy efficiency, solution size, system safety, and reliability of the electronics used. This design guide will review the megatrends underlying the smart building revolution and their associated system challenges, from networking protocols all the way down to the hardware. It then examines new solutions for power management through several case studies.

¹ Architecture 2030

² Actual green building performance

Megatrends in Building Automation

Building operators increasingly manage larger buildings remotely, using the cloud. Their software platforms provide performance monitoring, data analytics, visualization, fault detection and diagnostics, and portfolio energy management. These automation systems monitor several variables in real time and analyze historical data to adjust the devices to provide comfort to users while complying with government regulations and tariff policies. By networking the equipment data to the cloud, analytics are run using advances in artificial intelligence (AI) to determine the action to be taken. The most prevalent use of automation in buildings is in HVAC (heating/ventilation/air conditioning), lighting, monitoring, access control, fire detection, and surveillance using CCTV (closed circuit television).

A building's energy is measured by energy use intensity (EUI) and is noted in kilo British thermal units per square foot (KBTU/SF). One KBTU equals 3.142kWh.

Building Automation Systems

Building automation system architecture (Figure 2) includes different layers for management, control, and the field.

The management layer operates and controls the smart building from one central location, recording and optimizing data as necessary. Problems are spotted in real time so that action can be taken immediately. This layer uses network protocols like BACnet and Modbus.

The control layer (the building automation block shown in Figure 2) deals specifically with the building's equipment control at the hardware level. Here, decentralized protocols like KNX and LonWorks are used.

At the field layer, intelligent sensors and actuators collect data and perform tasks. For example, the building lighting level is sensed and automatically adjusted to match the time of day. Shading is provided to ensure optimal use of natural light without glare.

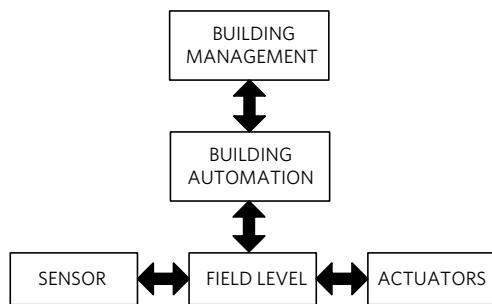


Figure 2. Smart Building System

Technology Enablers

All this intelligence, networking, and control is enabled by phenomenal advances in hardware and software. At the field level, it is manifested through controllers, sensors, I/Os, and actuators. A controller includes a programmable logic controller (PLC), motor/motion controller, or a distributed control system (DCS) using advanced processors and microcontrollers. Sensors are either digital or analog and used to measure temperature, humidity, ventilation, and occupancy. Actuators are used in locks, window alarms, security camera positioning, solar panels, blinds, and other moving mechanisms. In a modern building, sensors and actuators can communicate over wire or wireless gateways to the control center. They are powered by batteries or wired DC voltages, typically in the 5V to 24V+ range. In Figure 3, wireless sensors connect to the monitoring system via a gateway to detect the humidity, HVAC, and temperature.

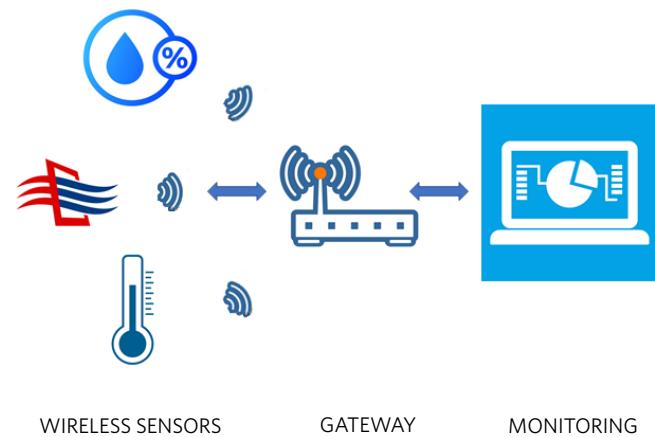


Figure 3. Wireless Sensors at Work

The controller receives inputs from sensors in the field, processes them, and drives the proper actuators. Today's sensors and actuators are equipped with internal processors that make simple decisions locally without the need for escalating them to the controller, thereby improving throughput.

The Challenges

The proliferation of intelligent, internet-connected equipment in smart buildings requires a proliferation of processors and connectivity interfaces into every controller, sensor, and actuator in the field. This, in turn, places new requirements on system hardware including: reduced component size to fit additional electronics in the same chassis, improved energy efficiency to perform within the same or smaller thermal budget, and increased electrical/mechanical safety and reliability to reduce downtime. In summary, the challenges for the electronic components are:

1. Higher Energy Efficiency
2. Reduced Solution Size
3. Increased Safety and Reliability

In the following sections, we will present a few examples of how power management electronics can come to the rescue in each case.

Challenge 1 - Higher Energy Efficiency

Case Study: Design 20W to 30W power supplies with over 90% efficiency for +24V building automation systems

The smaller PCB size that results from miniaturization presents a challenge for thermal dissipation. Thermal management options, such as heatsinks, are ruled out since board space is at a premium. Fans for forced airflow cannot be used due to sealed enclosures that prevent ingress of dust and pollutants. Therefore, it is crucial that the power-supply solution is extremely efficient while delivering higher power and occupying a smaller area than ever before.

Solving the Power Dissipation Problem

Often sensor and actuator applications are characterized by a 24V nominal DC voltage bus that has a history in old analog relays and remains the de-facto industry standard. However, the maximum operating voltage for industrial applications is expected to be 36V to 40V for non-critical equipment, while critical equipment, such as controllers, actuators, and safety modules, must support 60V (IEC 60664-1 insulation and 61508 SIL standards). Popular output voltages are 3.3V and 5V with currents varying from 10mA in small sensors to tens of amps in motion control, CNC, and PLC applications. Thus, the obvious choice for building and industrial control applications is a step-down (buck) voltage regulator.

The most common step-down architecture available is the nonsynchronous buck converter because it is easy for semiconductor manufacturers to design nonsynchronous buck regulators for high voltages. In this architecture, the low-side rectifier diode is external to the IC.

For a 24V input and 5V output, the buck converter works with a duty cycle of about 20%. This means that the internal high-side transistor (T in *Figure 4*) conducts only 20% of the time. The external rectifier diode (D) conducts the remaining 80% of the time, which accounts for most of the power dissipation.

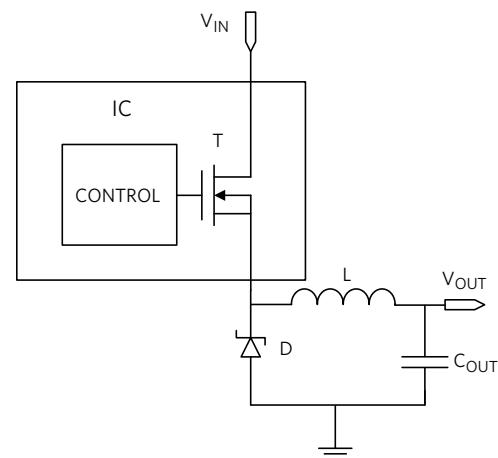


Figure 4. Nonsynchronous Buck Converter

As an example, with a 4A load, a Schottky rectifying diode such as the B560C, exhibits a voltage drop of about 0.64V. Consequently, at an 80% duty cycle, the conduction loss (the dominant loss at full load) is approximately equal to $(0.64V) \times (4A) \times (0.80) = 2W$, which is dissipated as heat.

On the other hand, if we utilize a synchronous architecture (*Figure 5*), the diode is replaced with a low-side MOSFET that acts as a synchronous rectifier. We trade off the 0.64V drop across the diode with the drop across the MOSFET transistor's T_2 on-resistance, $R_{DS(ON)}$.

In our example, the MOSFET (RJK0651DPB) has an $R_{DS(ON)}$ of only 11mΩ. This leads to a corresponding voltage drop of only $(11m\Omega) \times (4A) = 44mV$ and a power loss of only $(0.044V) \times (4A) \times (0.80) = 141mW$. The MOSFET power loss is about 14 times smaller than the Schottky power loss at full load! Clearly, the logical way to minimize power dissipation is to use synchronous rectification.

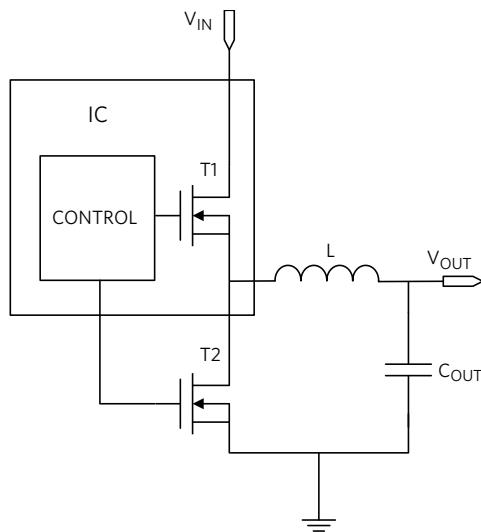


Figure 5. Synchronous Buck Converter

To minimize the overall size of the power-supply circuit, the synchronous rectifier IC should include internal compensation. Newer synchronous rectifiers provide internal compensation for any frequency and output voltage without requiring an oversized output capacitor that hurts bandwidth. The rectifier should also operate at high frequencies to allow the use of small inductors and capacitors.

Naturally, the goal is to fully integrate the entire synchronous rectification half-bridge (T₁ and T₂) into the IC, as illustrated in Figure 6.

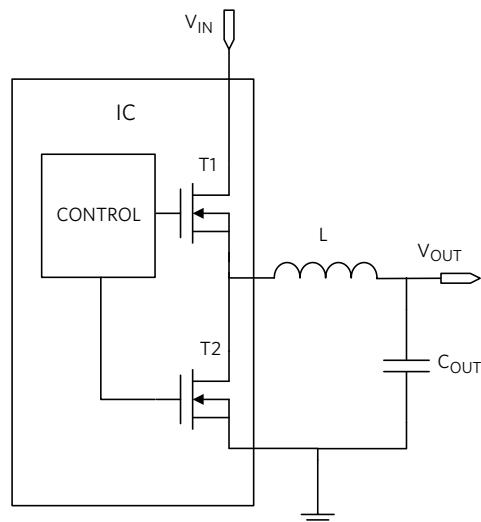


Figure 6. Fully Integrated Synchronous Buck Converter

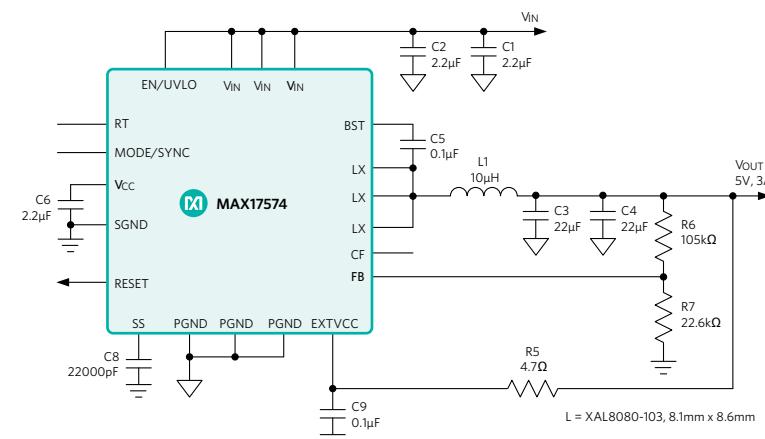
A Word of Caution on Maximum Input Voltage

While 24V is the nominal rail for many applications, it is important to carefully consider the maximum operating voltage. Today, there are 28V, 36V, 42V, or 60V input power management solutions available. With a margin of only 4V, 28V is too close to 24V to provide a reliable margin. Many standards require 60V tolerance, removing the need to make a choice. Although it may be tempting to choose a device with a 36V maximum input, using this level of input is a high-risk approach for sensors and encoders that work on a 24V rail. Even if TVS (transient voltage suppressor) diodes are used for surge protection, they have a wide tolerance and could still expose equipment to excessive voltages. Unless you are certain and have modeled every possible surge scenario resulting from long cables and PCB traces, use devices with a 42V or 60V maximum operating voltage even if the standard does not require it.

No Need for Trade-Offs

Our Himalaya family of high-voltage buck converters implements synchronous rectification for higher efficiency. Himalaya regulators feature input voltages up to 60V and output currents from 25mA to 50A, with fully integrated dual MOSFETs for devices that support loads up to 3.5A. Tagged with the slogan "Bye-Bye Schottky," Himalaya buck converters include internal compensation that does not require settling for the trade-offs discussed earlier.

Figure 7 shows the **MAX17574**, 4.5V to 60V, 3A fully integrated buck converter configured for 5V output.

Figure 7. Typical Application Circuit for MAX17574 24_{VIN}/5_{VOUT} 3A Synchronous Rectification Buck Converter

An efficiency comparison of the MAX17574 versus a competing synchronous solution, based on published specifications, is shown in *Figure 8*. The MAX17574 shows an efficiency advantage of up to 5%.

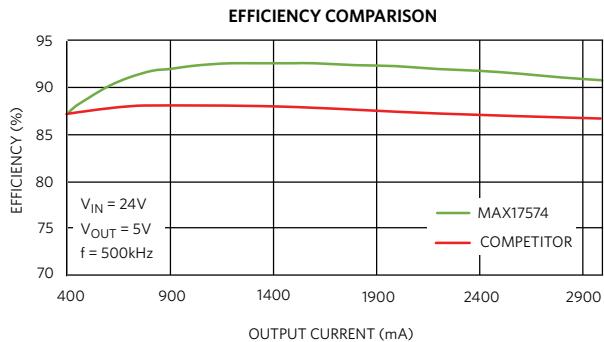


Figure 8. Efficiency Comparison Between MAX17574 and Another Synchronous Buck Converter

For higher current, the **MAX17506**, 5A synchronous rectification buck converter can be used. *Figure 9* shows the MAX17506 application diagram for a $24V_{IN}$, $5V_{OUT}$, 4A, 20W solution.

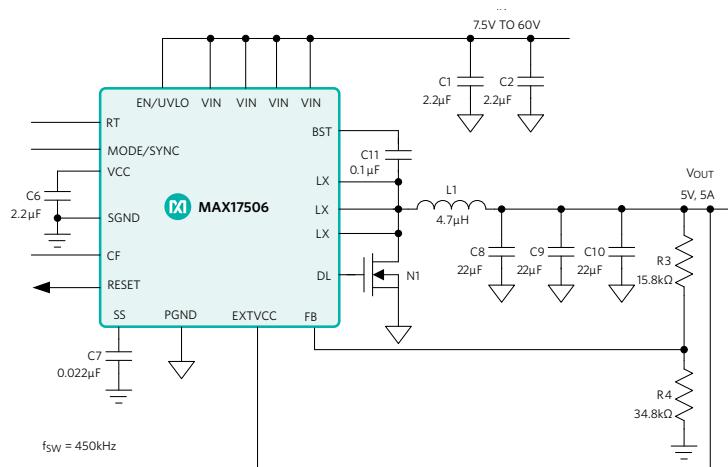


Figure 9. Typical Application Circuit for MAX17506 24V_{IN}/5V_{OUT}, 4A Synchronous Rectification Buck Converter

An efficiency comparison of the MAX17506 versus a nonsynchronous solution, based on published specifications, is shown in Figure 10. For both devices, the test conditions are a 24V input and a 5V, 4A output. As expected, the synchronous solution exhibits higher efficiency across the entire load current range. At full load (4A), the efficiency of the synchronous solution is above 92% while that of the nonsynchronous device is only about 86%, a difference in efficiency of more than 6% that translates into a reduced temperature rise.

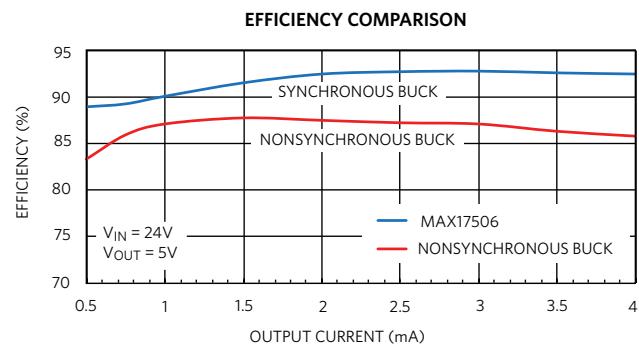


Figure 10. Efficiency Comparison Between MAX17506 and a Nonsynchronous Buck Converter

The MAX17506 synchronous solution demonstrates a clear efficiency advantage that eases thermal management challenges in industrial applications.

With the industry's first 60V synchronous buck regulators, our Himalaya family combines high efficiency and small size to cover a wide range of design requirements.

Case Study: Leverage a power module for faster time-to-market

Built using Himalaya voltage regulator ICs, our Himalaya power modules enable cooler, smaller, and even simpler power-supply solutions. The **MAXM17504** (Figure 11) is an easy-to-use, step-down power module that combines a switching power-supply controller, dual n-channel MOSFET power switches, a fully shielded inductor, and compensation components in a low-profile, thermally efficient, system-in-package (SiP) framework.

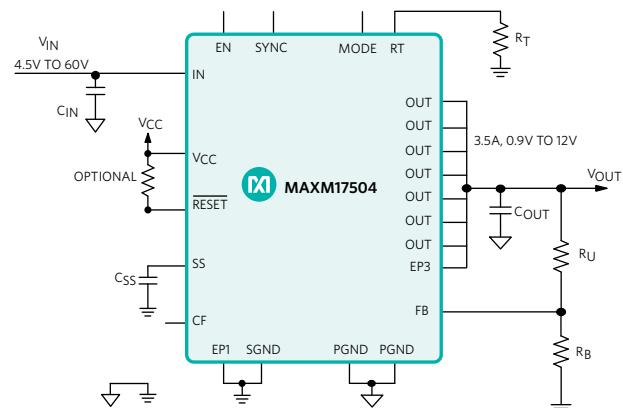


Figure 11. MAXM17504 Power Module

The MAXM17504 operates over a 4.5V to 60V wide input voltage range and delivers up to 3.5A continuous output current with excellent line and load regulation over a 0.9V to 12V output voltage range. The device only requires five external components to complete the total power solution. The device's high level of integration significantly increases reliability, reduces design complexity, reduces manufacturing risks, and offers a true plug-and-play power-supply solution that accelerates time-to-market. The MAXM17504 is available in a 29-pin, highly thermal-emissive, low-profile 9mm x 15mm x 2.8mm SiP that reduces power dissipation in the package and enhances efficiency. The package is easily soldered onto a PCB and is suitable for automated circuit board assembly. The device operates over the temperature range from -40°C to +125°C.

Challenge 2 - Reduced Solution Size

Case Study: Pack more punch in your small sensor while keeping it cool

Sensors have become ubiquitous in the smart home environment. In turn, sensor electronics are becoming more complex, requiring on-board voltage regulators to deliver power more efficiently with minimal heat generation. How do you safely deliver low-voltage power to tiny sensors, while minimizing solution size and maximizing efficiency? In this section, we will review a typical sensor architecture and provide a simple solution to this challenge.

Smart Home Sensor Applications

Sensors (*Figure 12*) detect and diagnose many parameters and make decisions. They must be durable and reliable regardless of the environment.

Sensors may be located anywhere in the building. The sensor "box" is powered by a voltage regulator, which delivers the appropriate voltage to the ASIC/microcontroller/FPGA, AFE, and sensing element.



Figure 12. Temperature and Humidity Sensor

Safe Low-Voltage Operation

The sensor is typically powered by a 24V DC power source. However, a building can be a very challenging environment to install sensors, which require long cable connections to the power source that result in high-voltage transients. Accordingly, the step-down converter inside the sensor must withstand voltage transients of 42V or 60V, which are much higher than the sensor operating voltage. As discussed before, for 24V rails, it is best to rely on devices that have an operating maximum of 42V. According to SELV/PELV/FELV (Safety/Protection/Functional Extra Low Voltage) regulations, an isolated device that handles up to 60V is considered safe to touch. Protection above 60V is provided with the addition of dedicated TVS devices.

Powering the Sensing Elements

Most industrial sensing elements need an input voltage significantly lower than the one supplied by the system to power digital and analog ICs. With increasing currents, as illustrated earlier, traditional LDO regulators are not viable solutions due to excessive heat dissipation. *Figure 13* shows the case in which an LDO is used to step-down a 24V system voltage to 5V to power the microcontroller and the sensing elements. This is a lossy process ($\eta = 21\%$) that ends up costing 1.3W of input power.

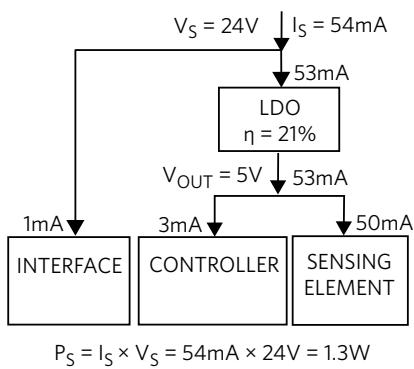


Figure 13. LDO-Powered Sensor

In *Figure 14*, the voltage step-down is performed by a simple switching regulator with 85% efficiency at 50mA.

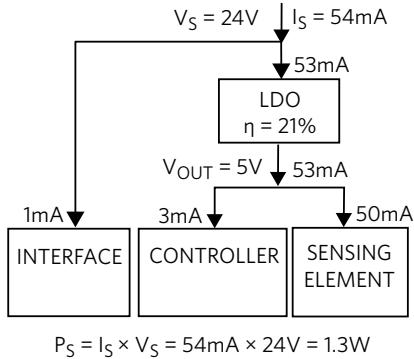


Figure 14. Buck-Powered Sensor

Here, the buck converter transfers power with an efficiency higher than an LDO, resulting in an input power of only 336mW.

A Tailor-Made Buck Converter Family

The **MAX15062** and **MAX15462** high-efficiency, high-voltage, synchronous step-down DC-DC converters are part of the Himalaya family. They save space with integrated MOSFETs and operate over a 4.5V to 60V and 4.5 to 42V input voltage range, respectively. Delivering output current up to 300mA, the devices are ideal for sensor applications. The low-resistance, on-chip MOSFETs ensure high efficiency at full load and simplify PCB layout. The devices offer programmable switching frequency to optimize solution size and efficiency and are available in compact 8-pin (2mm x 2mm) TDFN packages. Simulation models are available. We will further examine the MAX15462 in our discussion. Since both the MAX15462 and MAX15062 are pin-compatible, they have the same performance—the only difference is the maximum input voltage they support.

Figure 15 shows the typical application circuit for the 5V fixed configuration—optimized for small PCB size—delivering 5V to a load up to 300mA. The MAX15462A version has a 3.3V fixed output voltage and the MAX15462C version supports adjustable output voltages.

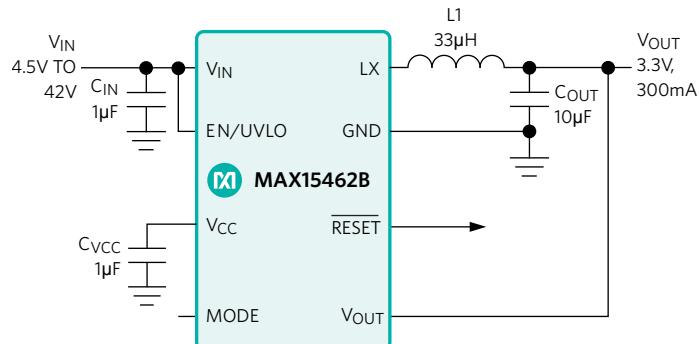


Figure 15. MAX15462B Typical Application Circuit

Figures 16 shows the typical efficiency curves at various input voltages with 5V output. With a 24V input, the peak efficiency is 90%. As shown earlier, these devices decisively outperform any LDO-based solution in terms of power savings.

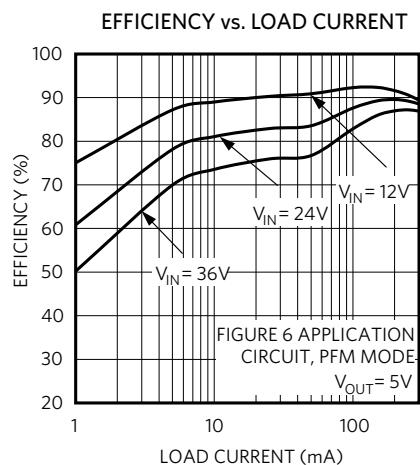


Figure 16. MAX15462B Typical Efficiency Curves

A PCB layout for the MAX15462, operating at 24V_{IN} with a 300mA output, is shown in Figure 17. While Himalaya ICs have transformed the industry with their small size, the constraints of the one-dimensional layout and size of the passives still stresses utilization (net component area of 28.12mm²). Compared to a traditional synchronous buck regulator solution that only delivers 150mA, this solution is 12.5% smaller.

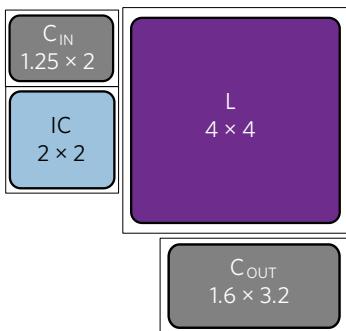


Figure 17. MAX15462 Buck Converter Layout
(Net Component Area 28.12mm²)

Note that manufacturing guidelines on the clearance between components will add additional area. This approach requires some knowledge of switching regulator design/testing to optimize component value/size.

Traditional Module Solutions Fall Short

To specifically address ease of use and reduce time to design and testing, many vendors have developed switching regulator modules. A typical switching regulator module that houses the buck converter IC and the inductor in a single package is shown in Figure 18. This solution attempts to address the ease-of-design and efficiency requirements, but clearly falls short in the PCB area utilization for space-constrained sensors. In this example, at a net component area of 47.2mm², the module solution takes up 68% more area than the discrete DC-DC regulator solution shown in Figure 17.

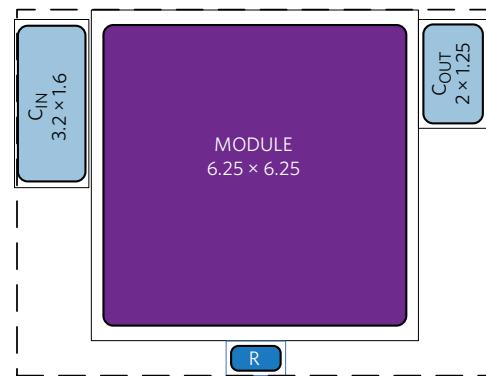


Figure 18. Traditional Buck Converter Module Layout
(Net Component Area 47.2mm²)

Case Study: Add more power density than ever to your small sensor

The electronics industry continues to find ways to pack more data in the same space, first with Moore's Law for silicon, and then beyond ("More than Moore") with sophisticated multidimensional IC packaging techniques. These techniques help push the power density envelope by packing more Watts in the same square millimeters. In this section, we introduce a disruptive approach in pushing the power density envelope for industrial sensors even further with a novel, miniaturized, easy-to-design, high-performance solution.

Himalaya uSLIC™ Power Modules

Can more power be delivered in a solution size even smaller than the best IC and traditional SiP module solutions without sacrificing the efficiency and reliability benefits required for low-current sensors? Effectively, the quest is for an LDO-like size with all the benefits of a switching regulator! A revolutionary technology has been developed which co-packages a state-of-the-art Himalaya buck converter with passive components in a micro-sized system-level IC (uSLIC). The Himalaya uSLIC power module delivers more power in a smaller space than ever before, with high efficiency, ease of use, and faster time to market.

uSLIC Power Module Specifications

The uSLIC power module vertically integrates the inductor and the buck converter IC, dramatically reducing the PCB space occupied by the standard buck converter solution. This still meets expectations of high-voltage tolerance and high-temperature operation. The **MAXM17532** module (Figure 19) is available in a low-profile, compact 10-pin, 2.6mm x 3mm x 1.5mm uSLIC package. It shows the dramatic size reduction achieved with the MAXM17532, 100mA, 42V buck converter uSLIC module. The device operates over a wide temperature range from -40°C to $+125^{\circ}\text{C}$. The ability to meet a 42V maximum operating voltage (not just absolute maximum) and support output voltages below 1.8V (to support the latest digital ICs), distinguishes a highly reliable product from other the run-of-the mill varieties. For higher loads, the **MAXM15462** provides up to the 300mA output in the same form factor.

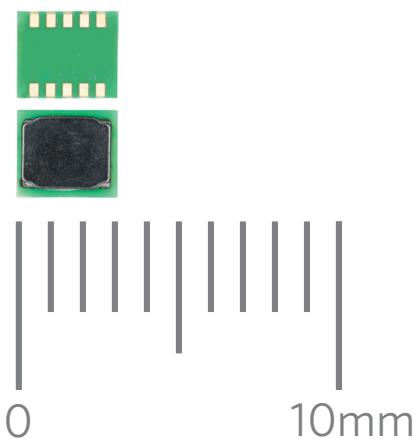


Figure 19. Less Than 8mm² Footprint of the MAXM17532 uSLIC Buck Converter

Miniaturized Size

Figure 20 shows the PCB for a complete power-supply solution using the MAXM17532 switching regulator module with a net component area of a mere 14.3mm².

Compared to the best IC solution of Figure 17, the Himalaya uSLIC module solution's net component area is 2x smaller. Compared to the traditional module of Figure 18, the uSLIC module solution is 3.3x smaller.

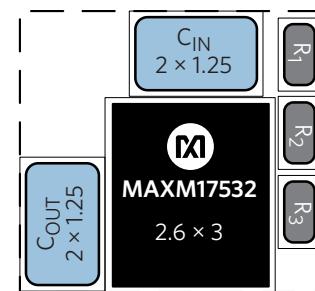


Figure 20. MAXM17532 uSLIC 5V_{OUT}, 100mA Buck Solution (Net Component Area 14.3mm²)

Figure 21 shows the uSLIC module housed in a small, M8-sized proximity sensor. Clearly, the uSLIC module consumes minimal space in this application.

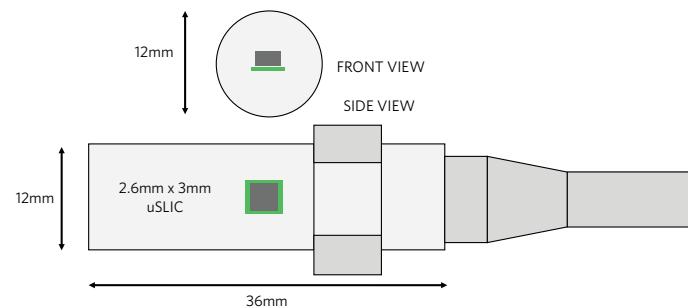


Figure 21. Buck IC, Inductor, and Sensor Size Comparison in a Proximity Sensor Application

High Efficiency

Figure 22 shows the efficiency of the MAXM17532 with 5V output and various input voltages. Despite the small size, the buck converter delivers high efficiency with peaks up to 90%.

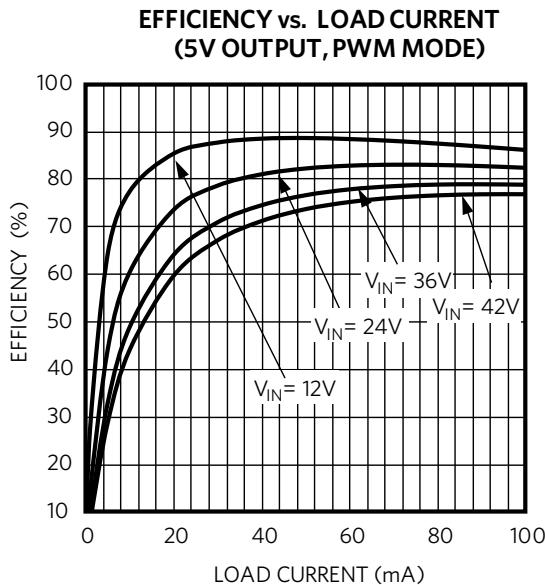


Figure 22. MAXM17532 uSLIC Power Module Efficiency

Low Emissions

The IC pinout is designed to minimize trace lengths and eliminate ground loops for minimum radiated emissions. The use of high-frequency ceramic capacitors minimizes conducted emissions. In a module, this is also done for the designer as the layout of the passive components' is handled inside the module. Figure 23 shows that the MAXM17532 radiated emissions comfortably meets the CISPR 22 Class B specification.

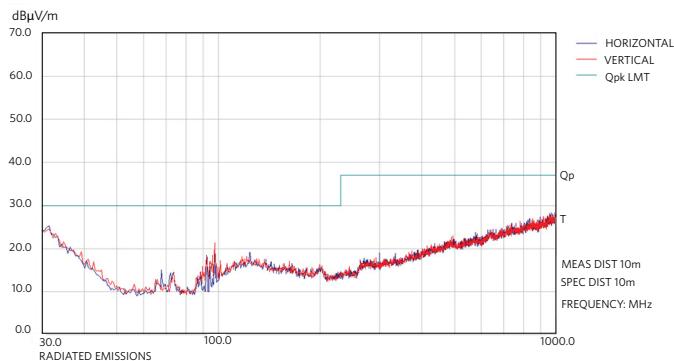


Figure 23. MAXM17532 Radiated Emissions

Figure 24 shows that the MAXM17532 conducted emissions also comfortably meets the CISPR 22 Class B specification.

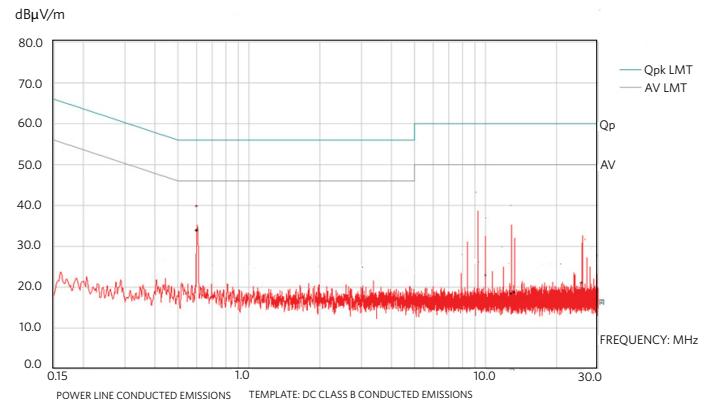


Figure 24. MAXM17532 Conducted Emissions

Drop, Shock, and Vibration Tolerance

Beyond thermal, electrical, and electromagnetic performance, it is important that power supplies are tolerant of mechanical stresses. Himalaya uSLIC modules meet JESD22-B103/B104/B111 standards for drop, shock, and vibration guaranteeing fool-proof operation in sensors deployed in harsh building environments.

Higher Current

For higher loads, the MAXM15462 Himalaya uSLIC module outputs up to 300mA with the same package as the MAXM17532, and provides similar benefits for solution size, efficiency, CISPR 22 compliance, as well as shock, drop, and vibration tolerance.

Challenge 3 - Increased Safety and Reliability

Case Study: Design smaller, more reliable, more efficient isolated power supplies

Isolated DC-DC voltage regulators are found in the most diverse applications. Although an isolated solution is more complex than a non-isolated one, there is still an expectation for it to fit in a small space and be highly efficient. In this case study, we discuss the reasons for isolation in low-voltage power conversion systems.

Low-Voltage Isolated Systems

According to SELV/FELV regulations, input voltages below 60V are considered inherently safe to touch, but the need for isolation in this operating range is still pervasive for functional safety and reliability reasons. In this voltage range, the power-supply electronic load, typically a very delicate and expensive microcontroller, needs protection. It could readily self-destruct if accidentally exposed to high voltage.

Isolation also prevents ground loops, which occur when two or more circuits share a common return path. Ground loops produce parasitic currents that can disrupt the output-voltage regulation as well as introduce galvanic corrosion of the conducting traces. This is a phenomenon that degrades equipment reliability.

Traditional Implementation

Using galvanically isolated transformers with PWM control is the most common architecture for an isolated DC-DC power supply. The flyback converter is the classic architecture that produces an isolated output. *Figure 25* shows the traditional implementation. During the "ON" time of the transistor T_1 , the voltage across the primary winding is positive (equal to V_{IN}) and the voltage across the secondary winding is negative. Consequently, the Schottky diode (SD) prevents energy from passing to the output and the energy is stored in the transformer. During the "OFF" time of T_1 , the primary winding inverts its voltage, which allows the energy to be released to the output. The control loop is quite complex, often requiring a shunt regulator (TL431A) on the secondary to regulate the voltage at the output. An optocoupler and error amplifier on the secondary-side of the transformer provide the isolated feedback signal needed to close the PWM control loop to the primary side.

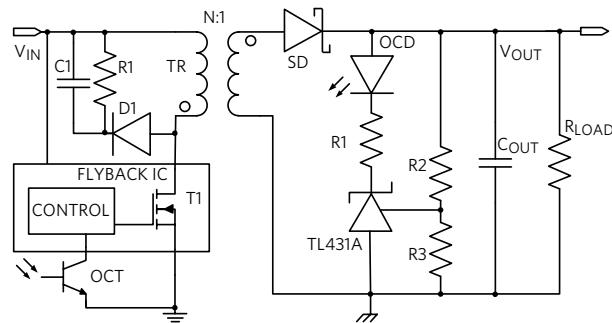


Figure 25. Flyback with Optocoupler

This solution, which utilizes two ICs and many passive components, is typically expensive, inefficient, and space consuming.

No-Opto Flyback Implementation

Since the transformer is magnetically coupled, the secondary winding voltage is reflected on the primary winding. The **MAX17690** samples and senses this isolated output voltage on the secondary-side directly from the primary-side flyback waveform during the off-time of the primary switch. No auxiliary winding or optocoupler is required for output voltage regulation. The patented MAX17690 is a peak current-mode, fixed-frequency switching controller, part of our Rainier family of isolated "Bye Bye Optocoupler" solutions. It is specifically designed for the isolated flyback topology operating in discontinuous conduction mode (DCM). Like a traditional flyback, 3% to 5% regulation accuracy is possible. However, the solution size is reduced by 30%. *Figure 26* shows a typical application.

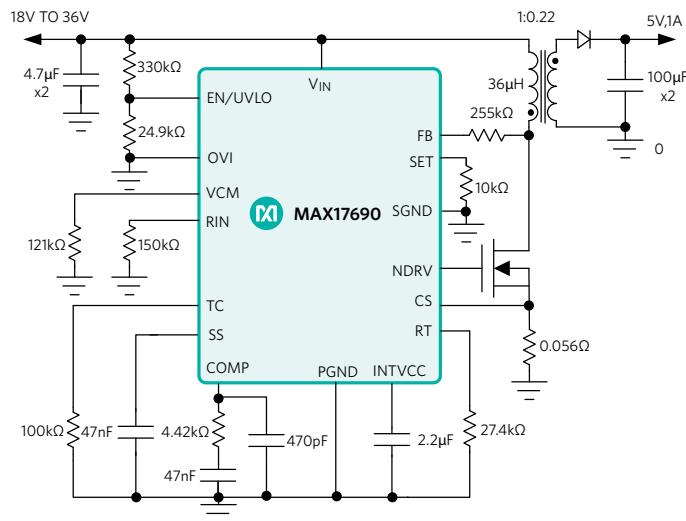


Figure 26. No-Opto Flyback Controller

The MAX17690 is designed to operate over a wide supply range from 4.5V to 60V. The switching frequency is programmable from 50kHz to 250kHz. An EN/UVLO pin allows the user to turn on/off the power supply precisely at the desired input voltage. The MAX17690 provides input overvoltage protection through the OVI pin. The 7V internal LDO output of the MAX17690 makes it suitable for switching both logic-level and standard MOSFETs used in flyback converters. With 2A/4A source/sink currents, the MAX17690 is ideal for driving low $R_{DS(ON)}$ power MOSFETs with fast gate transition times. The MAX17690 provides an adjustable soft-start feature to limit the inrush current during startup. Application Note 6394: *How to Design a No-Opto Flyback Converter with Secondary-Side Synchronous Rectification* is available to provide additional understanding of the topology.

The MAX17690 provides temperature compensation for the output diode forward-voltage drop. With robust hiccup protection and thermal protection schemes, it is available in a space-saving, 16-pin, 3mm x 3mm TQFN package with a temperature range from -40°C to +125°C.

Unlike above, if tight regulation accuracy is not critical and a small, compact, isolated power supply solution is still required without an optocoupler, a novel iso-buck topology is another option, as outlined in the blog, *Why Iso-Buck Converters are Better than Flyback Converters*.

Case Study: Choose the right protection for your smart load for improved system safety and reliability

Protection circuits are the unsung heroes of today's electronics. The long electrical chain, from the AC line to the digital load, no matter the application, is interspersed with fuses and transient voltage suppressors of all sizes and shapes. While common issues like ESD protection and pin-to-pin short circuits are handled within ICs, there are additional aspects to consider for safety and reliability. Along the electrical path, electrical stressors—such as inrush currents due to storage capacitors, reverse currents due to power outages, overvoltages, and undervoltages induced by inductive load switching or lightning—can damage precious electronic loads. This is true for microprocessors and memories, which are built with fragile sub-micron, low-voltage technologies. Layers of protection are necessary to handle these potentially catastrophic events (Figure 27).

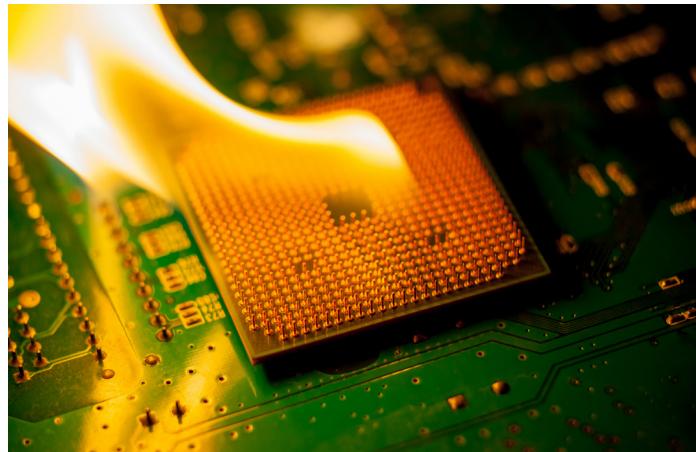


Figure 27. Unprotected CPU on Fire

Typical System Protection

Figure 28 shows a typical system protection scheme around the smart load, for example, a microprocessor. A DC-DC converter—complete with control (IC_2), synchronous rectification MOSFETs (T_3, T_4), associated intrinsic diodes (D_3, D_4), and input and output filter capacitors (C_{IN}, C_{OUT})—powers the microprocessor. A voltage surge from the 48V power bus (V_{BUS}), if directly connected to V_{IN} , would have catastrophic consequences for the DC-DC converter and its load. For this reason, front-end electronic protection is necessary. Here the protection is implemented with a controller (IC_1) that drives two discrete MOSFETs, T_1 and T_2 . Some control scheme designs use discrete components or a CPLD/microcontroller.

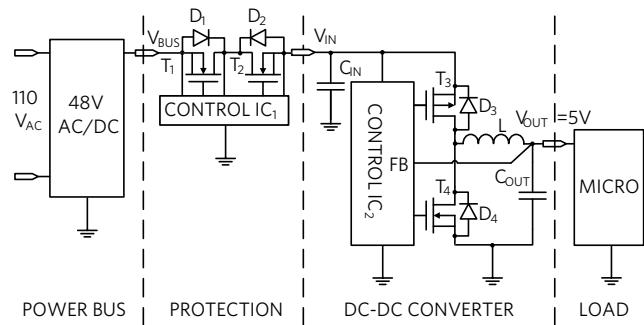


Figure 28. Typical Electronic System with Protection

Protection electronics must handle fault conditions such as overvoltage/undervoltage, overcurrent, and reverse-current flow within the limits of its voltage and current rating. If the expected voltage surge exceeds the protection electronics ratings, additional layers of protection are added, in the form of filters and TVS devices. *Figure 29* illustrates a case of hot plug-in, which has the potential to cause voltage surges.



Figure 29. Hot Plug-In Causes Voltage Surges

Overvoltage Protection

Arc fault protectors and TVS diodes protect against lightning surges and catastrophic high-voltage events. But protection is still needed when you get down to the main input bus (48V in the example above or a typical 24V in industrial applications. Hot-plugging (*Figure 29*) causes supply bounce while ringing due to long cable inductance (*Figure 30*), which also causes voltage surges.

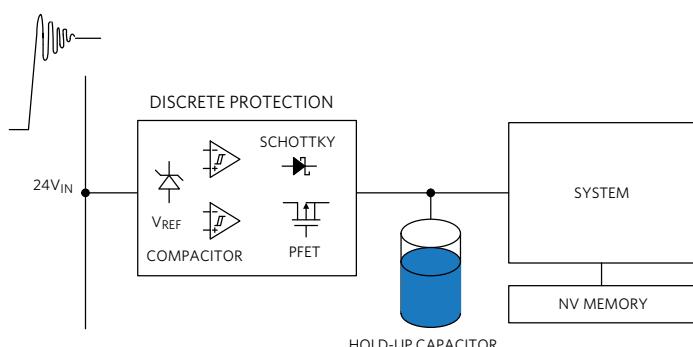


Figure 30. Cable Ringing Causes Voltage Surges

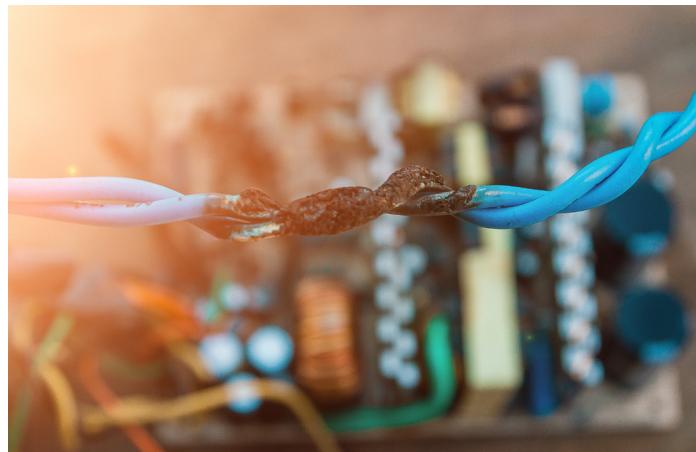


Figure 31. Heat-Damaged Electric Wires – Cable Faults Result In Short-Circuit Faults

Even when the incoming voltage is confined within the allowed operating range, problems can persist. Upward voltage fluctuations and large storage capacitors generate high CdV/dt inrush currents that can blow a fuse or overheat the system (*Figure 31*), reducing its reliability. Accordingly, the protection circuit (*Figure 32*) must be equipped with a current-limiting mechanism. Also, in operation, it is not uncommon to face both hard and soft short-circuit faults, from which protection is needed.

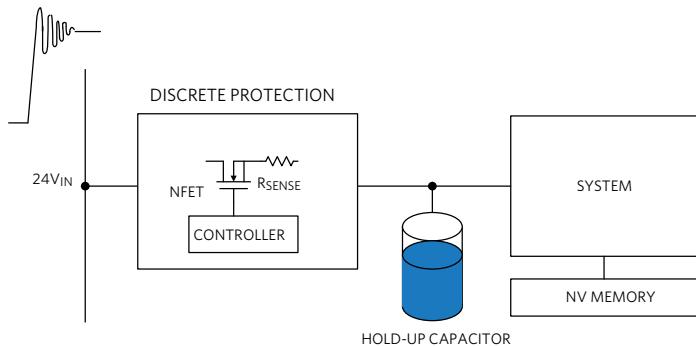


Figure 32. Current-Limit Protection Illustration

Reverse-Voltage/Reverse-Current Protection

Supply reversal can also occur due to improper cabling or operator errors that require reverse-polarity protection. Reverse-current protection is also an important need. In motor drive applications, the DC motor current is PWM-controlled with a MOSFET bridge driver. During the OFF portion of the PWM control cycle, the current recirculates back to the input capacitor. Similar applications exist in other building automation equipment, which result in sinking current that cause equipment failures.

Discrete Protection Circuits

Protection in most systems starts as a simple discrete circuit, typically designed to minimize component costs (*Figure 33*). However, as the final system goes through multiple phases of type testing and field deployments, more and more protection must be added. This increases costs and PCB area. A smart design practice is to first choose intelligent system protection ICs to mitigate problems late in the product development cycle.

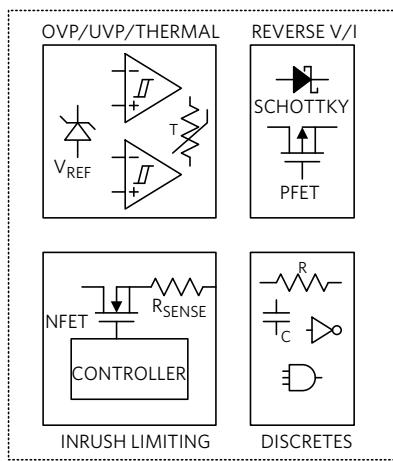


Figure 33. Discrete Protection Circuits Found in Most Systems

Integrated Solution

Figure 34 shows an integrated protection circuit that addresses overvoltage, reverse polarity, current limiting, reverse current, and short-circuit protection with all the benefits of an e-fuse and surge stopper. Designers can easily implement robust protection in their smart building equipment and pass compliance with configurable pins to set UVLO/OVLO, current limit, real-time voltage, and current monitoring, current thermal foldback, thermal shutdown, and other features.

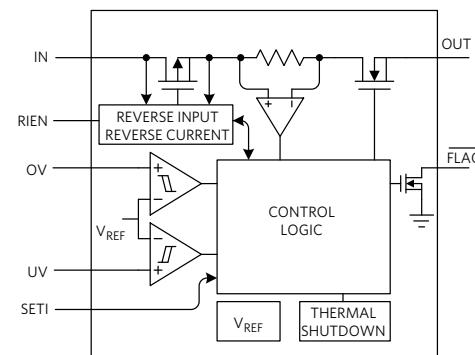


Figure 34. Integrated Protection in a Single IC

Integrated Protection Family

The Olympus family of protection ICs provides adjustable overvoltage and overcurrent protection. As an example, the **MAX17523** adjustable overvoltage and overcurrent protection device is ideal for protecting systems against positive and negative input voltage faults up to $\pm 40V$, and features low $190m\Omega$ (typ) R_{ON} integrated FETs. The adjustable overvoltage range is between 6V and 36V, while the adjustable undervoltage range is between 4.5V and 24V.

The overvoltage-lockout (OVLO) and undervoltage lockout (UVLO) thresholds are set using optional external resistors. The factory preset internal OVLO threshold is 33V (typ), and the preset internal UVLO threshold is 19V (typ). The MAX17523 also features programmable current-limit protection up to 1A. The device can be set for autoretry, latch-off, or continuous fault response when an overcurrent event occurs. Once current reaches the threshold, the MAX17523 turns off after 21ms (typ) blanking time and stays off during the retry period when set to autoretry mode. The device latches off after the blanking time when set to latch-off mode. The device limits the current continuously when set to continuous mode.

The MAX17523 also features reverse-current and thermal shutdown protection. The MAX17523 is available in a small, 16-pin (3mm x 3mm) TQFN package. The MAX17523 operates over the -40°C to $+125^{\circ}\text{C}$ extended temperature range.

Electronic loads require protection from the effects of power outages and fluctuations, inductive load switching, and lightning. A typical protection solution with a low level of integration leads to inefficiencies in terms of PCB space and a large bill of materials. The MAX17523 integrated, highly flexible, low $R_{DS(on)}$ protection IC provides direct and reverse-voltage/reverse-current protection with minimal BOM and PCB space.

Summary

Table 1 is a summary of an example power management approach for the smart building.

Table 1. Power Management for the Smart Building

Challenge	Application	Products	Product Type
Energy Efficiency	Actuators, PLC, I/O, Motion Control	MAX17574 , 60V, 3A MAX17506 60V, 5A	IC
		MAXM17504 60V, 3.5A	SiP Module
Small Size	Sensors, Encoders, I/Os	MAX15062 60V, 300mA MAX15462 42V, 300mA	IC
		MAXM17532 100mA MAXM15462 300mA	uSLIC Module
Safety and Reliability	Isolation	MAX17690 60V, 5Vout, 1A No-Opto	IC
	Protection	MAX17690 60V, 5Vout, 1A No-Opto MAX17523 4.5V-36V, 1A	IC

Conclusion

As the current trend of automation and data exchange in the smart building continues unabated, designers will rely on new technologies and approaches to achieve higher level of comfort, reduce carbon footprint, and deduce cost. The adoption of these technologies introduces challenges in terms of energy efficiency, miniaturization, and system reliability. For each challenge we presented, we showed how power management can improve the design of building automation systems. For energy efficiency, we proposed two highly integrated, high-power buck converter ICs for high-performance systems from the Himalaya IC family and a power module for ease of design and fast time-to-market from the Himalaya SiP module family. Similarly, for sensors, we proposed two low-power, highly integrated ICs from the Himalaya IC family and two fully integrated power modules for highly space-constrained applications from the Himalaya uSLIC power module family. Finally, for safety and reliability, we presented a no-opto isolated flyback converter IC from the Rainier isolated family and a highly integrated protection IC from the Olympus protection family. These power management solutions overcome the critical challenges faced by today's smart buildings.

Glossary

AFE: Analog front-end

BACnet: A centralized network protocol for building automation at a management and automation level

CNC: computer numerical control

EUI: Energy use intensity, measured in KBTU/SF

FELV: Functional Extra Low Voltage. A non-isolated circuit below 60V

Field Device: A building automation umbrella term for sensors and actuators

BTU: British thermal unit, 1kBTU equals 3.142 kWh

KNX: A decentralized network protocol for building automation at field level

LonWorks: A decentralized protocol for building automation at field level

Modbus: A centralized network protocol for building automation at management and automation level

PLC: Programmable logic controller. An industrial computer that monitors and controls a single manufacturing process. A PLC board is comprised of a CPU, I/O modules, memory/programming, and power supply

SELV. Separated Extra Low Voltage. An isolated circuit below 60V. Such circuits are considered safe to the touch

Product Selector Tables

Himalaya Wide Input Synchronous Voltage Regulators

Part	I _{OUT} (A)	V _{IN} (V)		V _{OUT} (V)		Frequency Range (MHz)	PFM Option	Package Type	Package Size (mm)
		Max	Min	Max	Min				
4.5V to 60V/76V Single-Output, Step-Down Regulators									
MAX17761	1.0	4.5	76.0	0.8	68.4	0.2 to 0.6	Yes	TDFN	3.0 x 3.0
MAX17550	0.025								
MAX17551	0.050	4.0	60.0	0.8	54.0	0.1 to 2.2	Yes	TDFN/µMAX	2.0 x 3.0/3.0 x 5.0 pin-compatible
MAX17552	0.1								
MAX15062⁽¹⁾	0.3				53.0	0.5	Yes	TDFN	2.0 x 2.0
MAX17501⁽¹⁾	0.5				55.0	0.3/0.6	Yes ³	TDFN (TSSOP ³)	2.0 x 3.0 (3.0 x 3.0)
MAX17502⁽¹⁾	1.0					0.3/0.6		TDFN/TSSOP	2.0 x 3.0 / 4.4 x 5.0
MAX17572	1.0					0.4 to 2.2	No	TDFN	3.0 x 3.0
MAX17575	1.5					0.2 to 2.2			
MAX17505	1.7	4.5	60.0	0.9	54.0	0.1 to 2.2	Yes		4.0 x 4.0 pin-compatible
MAX17503	2.5					0.2 to 2.2			
MAX17574	3.0					0.1 to 2.2		TQFN	4.0 x 5.0
MAX17504	3.5					0.2 to 2.2			5.0 x 5.0
MAX17536	4.0					0.1 to 2.2			
MAX17506	5.0								5.0 x 5.0 pin-compatible
4.5V to 42V/60V Dual-Output, Step-Down Regulators									
MAX17521	1.0 per output			0.9	55.0	0.3/0.56	Yes	TQFN	4.0 x 5.0
MAX17558⁽²⁾		4.5	60.0						5.0 x 5.0
MAX17559⁽²⁾	10.0 per output			0.8	24.0	0.1 to 2.2	No	TQFP	7.0 x 7.0
MAX17548⁽²⁾			42.0					TQFN	5.0 x 5.0
4.5V to 36V Step-Down Regulators									
MAX17632	2	4.5	36	0.9	90% V _{IN}	0.4 to 2.2	Yes	TDFN	3.0 x 3.0

Notes:

1. Fixed 3.3V and 5.0V pin-compatible options available for even more compact designs.
2. Controller ICs for use with external MOSFETs to support high current applications.
3. Contact factory [Maxim Technical Support](#).

Himalaya Power Modules

Part Number	V _{IN} (V)		V _{OUT} (V)		I _{OUT} (A)	Frequency (MHz)		Package Type	Size (mm)			
	Min	Max	Min	Max	Max	Min	Max					
2.4V to 5.5V Step-Down Power Modules												
MAXM17514	2.4	5.5	0.75	5.5	4.0	1.0	1.0	SiP 28-pin	6.5 x 10 x 2.8			
MAXM17515					5.0							
MAXM17516					6.0							
4.5V to 42V Step-Down Power Modules												
MAXM17532	4.0	42.0	0.9	4.5	5.5	0.10	0.1	Micro-SLIC 10-pin	2.6 x 3.0 x 1.5			
MAXM15462	5.0				5.0	0.30	0.47					
MAXM17545					1.7	12.0	0.1					
MAXM17543					2.5		SiP 29-pin	9 x 15 x 2.8				
MAXM17544					3.5							
4.5V to 60V Step-Down Power Modules												
MAXM17502	4.5	60.0	0.9	12.0	5.0	1.0	0.3	SiP 28-pin	6.5 x 10 x 2.8			
MAXM17505					1.7	2.5	0.1					
MAXM17503					12.0		SiP 29-pin	9 x 15 x 2.8				
MAXM17574					2.5							
MAXM17504					15.0	3.0	2.2		SiP 33-pin			
					12.0	3.5	1.8		SiP 29-pin			

Rainier Isolated DC-DC Power Solutions

Part Number	Supply Voltage (V)		Feedback		FET	Frequency Range (MHz)	Package Type	Package Size L (mm) x W (mm)
	Min	Max						
DC-DC Peak Current-Mode Flyback Converters								
MAX17498B	4.5	36	Opto	Integrated	500	TQFN	3x3	
MAX17498C								
High-Efficiency, Iso-Buck DC-DC Converter								
MAX17681/A	4.5	42	Primary Side	Integrated	200	TDFN	2x3	
MAX17682								
No-Opto Flyback Controller								
MAX17690	4.5	60	Primary Winding*	External	50 to 250	TQFN	3x3	
Peak-Current-Mode Controllers for Flyback Applications								
MAX17596	4.5	36	Opto	External	100 to 1000	TQFN	3x3	
MAX17597								
Peak-Current-Mode Controllers for Active-Clamp Forward Applications								
MAX17598	8.0	29	Opto	External	100 to 1000	TQFN	3x3	
MAX17599	4.5	36						

*Output voltage regulated using the primary winding of transformers.

Part Number	V _{IN} (V)		Drive Source/Sink Current (A)	Turn-On Prop. Delay (nS)	Turn-Off Prop. Delay (nS)	Package Type	Package Size L (mm) x W (mm)
	Min	Max					
Secondary-Side Synchronous MOSFET Driver for Flyback Converters							
MAX17606	4.5	36	2/4	26	32	TSOT	2x3

EV Kit	Configuration	Input	Output	
MAX17681EVKITA	Iso-Buck	17V to 32V	±15V	100mA
MAX17681EVKITB			±7V	100mA
MAX17681EVKITC			+15V	200mA
MAX17681EVKITD		17V to 36V	+7V	200mA
MAX17681EVKITE			±15V	75mA
MAX17681EVKITF			±7V	75mA
MAX17682EVKIT			+24V	100mA
		16V to 42V	+12V	750mA

EV Kit	Configuration	Input	Output	
MAX17598EVKIT	Sync. Flyback	36V to 72V	3.3V	8A
MAX17498BEVKIT		+5V	1.5A	
MAX17596EVKIT		+24V	833mA	
MAX17597FBEVKIT		+24V	833mA	
MAX17690EVKITB		+5V	1A	
MAX17690EVKITCH		±15V	200mA	
MAX17606SFBEVKIT		+5V	3A	
MAX17690EVKITA		+5V	1A	

Olympus Overvoltage and Overcurrent Protectors

Part Number	V _{IN} (V)		Current Limit (A)		Fault Response	Dual-Stage Current Limiting ¹	Features	Package-Pin
	Min	Max	Min	Max				
MAX14571	4.5	36	0.7	4.2	Autoretry			TSSOP-EP/14
MAX14572	4.5	36	0.7	4.2	Latch-off			TSSOP-EP/14
MAX14573	4.5	36	0.7	4.2	Continuous			TSSOP-EP/14
MAX14588	4.5	36	0.15	1	Latch-off			TQFN-CU/16
MAX14691	5.5	58	0.6	6	Pin-selectable (latch-off, autoretry, continuous)	1.0x	OV, UV, OC, OT, reverse-current (external FET)	TQFN-CU/20
MAX14692	5.5	58	0.6	6	Pin-selectable (latch-off, autoretry, continuous)	1.5x	OV, UV, OC, OT, reverse-current (external FET)	TQFN-CU/20
MAX14693	5.5	58	0.6	6	Pin-selectable (latch-off, autoretry, continuous)	2.0x	OV, UV, OC, OT, reverse-current (external FET)	TQFN-CU/20
MAX14721	5.5	60	0.2	2	Pin-selectable (latch-off, autoretry, continuous)	1.0x	OV, UV, OC, OT, reverse-current (with external FET)	TQFN/20
MAX14722	5.5	60	0.2	2	Pin-selectable (latch-off, autoretry, continuous)	1.5x	OV, UV, OC, OT, reverse-current (with external FET)	TQFN/20
MAX14723	5.5	60	0.2	2	Pin-selectable (latch-off, autoretry, continuous)	2.0x	OV, UV, OC, OT, reverse-current (with external FET)	TQFN/20
MAX17525	5.5	60	0.6	6	Latch-off			TQFN-CU/20
MAX17561	4.5	36	0.7	4.2	Autoretry			TSSOP-EP/14
MAX17562	4.5	36	0.7	4.2	Latch-off			TSSOP-EP/14
MAX17563	4.5	36	0.7	4.2	Continuous			TSSOP-EP/14
MAX17608	4.5	60	0.1	1	Pin-selectable (latch-off, autoretry, continuous)		OV, UV, OC, OT, reverse-current protection (internal FET), FLAG and UV OV, signals	TDFN-EP/12
MAX17609	4.5	60	0.1	1	Pin-selectable (latch-off, autoretry, continuous)		OV, UV, OC, OT, FLAG and UV OV signals	TDFN-EP/13
MAX17610	4.5	60	0.1	1	Pin-selectable (latch-off, autoretry, continuous)			TDFN-EP/14

1. During initial startup period, the current limit is increased by the indicated ratios.

Related Resources

[Building Automation](#)

[Himalaya Power Modules](#)

[Himalaya Step-Down Switching Regulators](#)

[Isolated Power](#)

[Protection ICs](#)

Design Solutions

[Design 20W-30W Power Supplies with Over 90% Efficiency for 24V+ Industrial Automation Systems](#)

[Pack More Punch in Your Small Sensor While Keeping It Cool](#)

[Iso-Buck Converter Enables Smaller, More Efficient Isolated Power Supplies](#)

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Learn more

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www.maximintegrated.com/smartbuilding

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